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PORTABLE AUTOMATIC DATA RECORDING EQUIPMENT (PADRE) (U)

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PORTABLE AUTOMATIC DATA RECORDING EQUIPMENT (PADRE)

Prepared by:

James M. Kendall

ABSTRACT: The PADRE provides a means of automatically punching IBM cards to record data on pressures, forces and moments, temperatures, small temperature differences, mean square values of turbulence, positions of probes during boundary-layer surveys, angles of attack of models in wind tunnels, and any other analog quantity represented by a voltage. Seven channels of four decimal digits each are provided, besides a means of automatically punching a serial number or clock time into each card. Each of the seven channels has its own digital converter and may be operated with 60 cps input signals from strain gages or with D.C. input signals from either strain gages or thermocouples.

This equipment has been in use at the NOL Wind-Tunnel Facility since 1954. Because of its portability this equipment can be used with any of the NOL operating wind tunnels. Because of its versatility it is particularly useful for research work requiring special set-ups. Hence it complements and supplements the Automatic Data Processing System (ADAPS) and the high-speed data system to be installed in 1960.

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A wind-tunnel test facility costs several hundred dollars per hour to operate. On this account it is absolutely necessary that every effort be made to operate it in the most efficient manner. The Portable Automatic Data Recording Equipment (PADRE) was developed in response to this requirement and has proved to be a significant advance in this direction.

The following personnel have had a major part in the development, construction, maintenance, and operation of this equipment: Mr. George W. Payne, Mr. Ward J. Wilkie, and Mr. Milton R. Dixon.

This work was performed under Task No. NOL-502-825/51014/01.

MELL A. PETERSON
Captain, USN
Commander

R. KENNETH LOBB
By direction

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REFERENCE

(a) National Bureau of Standards NBS Circular 508 and RP-2415

PORTABLE AUTOMATIC DATA RECORDING EQUIPMENT (PADRE)

INTRODUCTION

1. Several years ago the need for some kind of automatic data recording device became apparent. For the apparatus to be of maximum service, it had to be portable, reliable, versatile, and simple to operate. An intensive development program was begun and resulted in PADRE (Portable Automatic Data Recording Equipment), which was put into operation at the NOL Wind-Tunnel Facility in 1954. Since then this equipment has complemented and supplemented the Automatic Data Processing System (ADAPS) and will augment the high-speed data system to be installed during 1960, particularly in the case of research activities for which a simple system is highly desirable.

2. Because of its portability, the PADRE makes it possible to bring to any of the operating tunnels in the NOL Wind-Tunnel Facility a means of automatically punching IBM cards to record data on pressures, forces and moments, temperatures, small temperature differences, and mean square values of turbulence, angles of attack, probe positions, etc., by means of transducers. For punching these types of data into IBM cards, seven channels of four decimal digits each are provided as well as a means for automatically punching a serial number or the clock time of day into each card. One servo-system is used in each channel, driving a digital converter directly. Each servo-system is arranged so that it may be operated with 60 cps input signals for use with strain gages or with D.C. input signals for use with either strain gages or thermocouples.

3. The seven channels with the associated control equipment are mounted on a relay rack which has rubber-tired casters for ease of movement. The type 026 IBM Card Punch is a separate piece of equipment mounted on a dolly and contains a keyboard which makes it possible to punch in by hand supplementary data as they arise during a test. After the cards are punched with the data, they are taken to the NOL computing facility where the cards are machine processed for data reduction.

4. PADRE is quite simple to operate; if need be, one man can operate both the PADRE and the wind tunnel. This feature makes PADRE particularly attractive in light of the manpower requirements of many wind-tunnel tests.

Elements of PADRE

5. The block diagram given in Figure 1 shows the over-all relationship between the various elements making up the PADRE. The model in the wind tunnel provides the signals which are to be recorded. These signals are fed directly into the servo-systems and cause them to come to balanced positions, carrying the digital converters to the corresponding readings. The digital converters are read out through the punch controller. The 026 IBM Card Punching Machine then records the readings on an IBM card, both by punching the proper holes and also by printing the same information at the top edge of the card. The readout of the serial number device or of the clock-time digital converter also goes through the punch controller so that time information may be punched along with the servo-system readouts.

Description of Servo-System

6. Figures 2 and 3 show schematic circuit diagrams of the PADRE servo-systems. Figure 2 shows the arrangement used for A.C. operation, while Figure 3 shows the arrangement for D.C. operation. The strain gage of Figure 2 or the thermocouple of Figure 3 is located in the model under test in the wind tunnel and produces the voltage to be measured which is fed into the PADRE. Referring now particularly to Figure 2, it is seen that a channel of servo-system consists essentially of a potentiometer through which flows the reference current, a Brown amplifier Part No. 353170-20 (amplification order of magnitude of 12 x 10^6), and a servo-motor which is a two-phase induction motor. The servo-motor is mechanically arranged to move the potentiometer arm in such a direction so that the error signal* fed to the amplifier is decreased. This signal is the difference between the incoming signal from the strain gage (Terminals C and D in Figure 2) and that from the potentiometer output (Terminals A and B). When the potentiometer arm is moved to the position where the incoming signal is exactly equal to the potentiometer output, the error signal is zero and the driving current fed to the motor by the amplifier is also zero, so that the motor rests in this position. The servo-system is then balanced. The position of the arm on the potentiometer is now an accurate measure of the magnitude of the incoming signal. A digital converter driven from the potentiometer shaft through gears is then able to

* The term "error signal" is used here in the sense ordinarily employed for servo-systems and automatic controls.

transform the (analog) position of the potentiometer shaft into (digital) decimal numbers representing the magnitude of the incoming signal.

7. As is true of servo-systems in general, the amount of amplification in the servo-system amplifier does not have a great effect on the sensitivity of the servo-system. However, if insufficient amplification is present, the balancing of the servo-system is not as accurate as it might be. On the other hand, too much amplification causes instability of the servo-system, usually indicated by oscillating about the balance point. The best amount of amplification to use is the highest which barely avoids oscillation; then the servo-system gives the best repeatability. The amplification required for this condition varies with the sensitivity of the servo-system; the greater the sensitivity, the greater the amplification required. The amplification control is located in the Brown amplifier chassis, where a plastic knob has been provided for varying the amount of amplification (see Figure 4).

8. No servo-potentiometers meeting the requirements of the PADRE were commercially available, so it was necessary to design and build the ones used. They have proved to be exceptionally reliable, rugged, and accurate, and the linearity is better than 0.1 percent. The resistance element is made from No. 14 B & S (0.064" dia.) solid Advance wire, the wire being of much larger size than that used in any known commercial potentiometers. The winding is of the double type with the brush making contact between the two windings as shown in Figures 2 and 3. This arrangement makes it possible to have the potentiometer essentially non-inductive so that stray A.C. magnetic fields do not produce troublesome interference.

9. As shown in Figure 2, an 11-step potentiometer makes it possible to have the servo-balance point located anywhere throughout the scale. With the centering potentiometer set at 5 and with the capacity balance adjusted to give maximum servo-stiffness, the resistance balance can be adjusted to set the servo-system on a reading of 1000. The centering potentiometer will then give even steps of 200 counts per step from 1000. This arrangement has proved to be of real convenience in operating the PADRE.

10. There are four terminals (labelled 1, 2, 3, and 4) connected to the strain gage (see Figure 2). These terminals, as shown in Figure 4, are the four binding posts located on

the right-hand side of the front panel. By connecting suitable resistors across these terminals, balance interactions present in wind-tunnel balances can be greatly reduced. When a thermocouple output is to be recorded, the servo-system of the PADRE must be connected for D.C. operation, as shown in Figure 3. Basically the D.C. circuit is the same as the circuit for A.C. operation, Figure 2, except that a chopper must be used in the circuit to convert the D.C. error signal into A.C before it is fed into the A.C. amplifier. Also, it is necessary to use a D.C. reference current in the potentiometer in place of the A.C. reference current used for A.C. operation of strain gages. The servo-systems in the PADRE are arranged so that converting them from A.C. to D.C. operation, and vice versa, can be accomplished within minutes.

11. It is to be noted that the potentiometer in the D.C circuit arrangement appears to be connected in a reversed direction. This has been done to eliminate the tribo-electric effect which prevents the servo from readily attaining a balance. In the A.C. connection the tribo-electricity is effectively nullified by the direction reversals of the alternating voltage used. Since tribo-electricity is of considerable importance for potentiometers working at the microvolt level, a brief explanation is in order. The wire used in potentiometer is made of some standard type of resistance wire (Advance, Nichrome, or Manganin), while the material of the brush riding along the wire is usually made of silver, platinum, or some other precious metal. Any sliding of a metal over a different metal has associated with it a certain amount of friction, which produces a minute amount of heat exactly at the point of contact. The two dissimilar metals form a very effective thermojunction, and a thermoelectric voltage is generated during sliding of a magnitude which is dependent on the amount of heat generated by the friction. The direction of the tribo-electricity is always the same, but the error signal fed to the amplifier may be of either direction, depending on the direction of unbalance. Hence the tribo-electricity can either increase or decrease the error signal. When it increases the error signal, it causes the servo-system to overshoot the balance point and thus introduces servo-instability. It is, therefore, desirable to avoid the effect, but this is practically impossible. For example, a brush made of the same materials as the resistance wire would eliminate the thermojunction at the point of contact, but any metal sliding on itself exhibits very serious wear, ruling out this mode of operating. The "swamping" of the tribo-electricity by using the potentiometer in the reversed connection shown in Figure 3 has been found to be a very satisfactory solution to this problem.

12. For A.C. operation, the reference current for each channel is obtained from one of the eight secondaries of a transformer. The strain gage exciting power is obtained from another secondary of 5 volts on the same transformer. Since voltages for both reference and for strain gage excitation come from the same transformer, the ratio of these voltages depends only on the transformer-turns ratio, and hence the voltage ratios are independent of line-voltage variations. Consequently, line voltage variations are without harmful effects. For D.C. operation, the required D.C. reference currents through the potentiometers are obtained from three No. 6 dry cells connected in parallel for each channel. It has been found that this arrangement gives a very constant source of D.C. current which obviously is also independent of line voltage variations. The effect of normal room-temperature variations is entirely negligible (less than 0.05%) on the D.C. reference current.

13. For A.C. operations, the sensitivity, number of counts per unit of signal magnitude, of the PADRE is controlled by two different methods which are independent of each other. A wide range of sensitivities is thus made available by the combined action of the two controls, giving much more range of sensitivity than would be practicable with either control alone. The simpler of these methods uses an attenuating network, or "signal attenuator," consisting of a symmetrical arrangement of variable series and shunt resistances. This network, shown in Figures 2 and 4, directly reduces the magnitude of the signal fed to the servo-system. The other method consists of an arrangement to control the reference current; the greater the IR voltage drop across the potentiometer, the less the potentiometer arm must be moved for the servo-system to become balanced for a given magnitude of signal, therefore, resulting in lower sensitivity of the servo-system. The second method of controlling sensitivity depends on the resistance network marked "sensitivity control" in Figure 2. For minimum sensitivity this control is set to position 1 which inserts 5 ohms in each side of the 0.375 volt transformer secondary, the output current of which is fed to the 0.1 ohm potentiometer. The reference current through the potentiometer is then 0.0375 amperes (approximately) and the IR drop in the potentiometer is 3750 microvolts. The total rotation of the potentiometer is arranged to give 2000 counts, both on the dial and on the digital converter. With the sensitivity control set to position 1, the sensitivity is then 18.75 microvolts per count. With the signal attenuator set to maximum attenuation, another factor of 10:1 decreasing the sensitivity is introduced, so that now 187.5 microvolts are required to give one count.

14. Maximum sensitivity is obtained when the sensitivity control is set on position 5, which introduces 200 ohms in the circuit. With the signal attenuator set to zero attenuation, the sensitivity is much greater than is normally needed and has not been used as yet.

15. When the PADRE is used to measure D.C. voltages such as from thermocouples, the sensitivity through the D.C. reference current is controllable by means of a rheostat for each channel. In this case, the value of the current is read on a laboratory-type millimeter. The maximum usable sensitivity is obtained with a reference current of about 0.010 amperes, which gives a sensitivity of about one-half microvolt per count.

16. Good repeatability of the PADRE depends very much on proper set-up. Generally, the greatest reference current possible for the particular sensitivity required gives the best repeatability and accuracy. Under normal conditions the repeatability is usually within one or two counts. The over-all accuracy, of course, involves the calibration. For the measurement of forces and moments with strain-gage balances, it is necessary to calibrate the over-all system by applying known weights to deflect the strain gages and recording the corresponding PADRE readings. The over-all accuracy should equal the repeatability if the inherent accuracy of the strain gage and its calibration do not limit accuracy otherwise. When pressures are to be measured, pressure gages making use of strain gages are used. For calibrating this system, known pressures are applied to the pressure gages and the resulting PADRE readings are punched into the IBM cards. A different situation is encountered in the measurement of temperatures. The PADRE is calibrated against known millivolt or microvolt inputs obtained from a "microvolt source" which has been calibrated against a Rubicon thermofree potentiometer or against a K-2 L & N potentiometer. It is generally advisable to use the microvolt source rather than an L & N potentiometer to provide the known input to the PADRE since the microvolt source has a low internal resistance while L & N potentiometers and other standard potentiometers generally have internal resistances which are too high for this purpose. With the PADRE now calibrated, a standard table of millivolts vs. temperature for thermocouple materials (reference (a)) can be used to obtain the temperature equivalents for known PADRE readings. With the maximum usable sensitivity of one-half microvolt per count (reference current of about 0.010 ampere) the thermocouple temperature indication with a

Cu-Constantan thermocouple is about 0.01°C per count. With careful operation this means an accuracy of about 0.01°C. This set-up is useful for measuring small differential temperatures. Such small differential temperatures result when temperature gradients are being measured in a wind-tunnel model. In effect, there are two thermojunctions spaced a known distance apart. The thermojunctions are connected in series so that the output "buck," thus giving the difference of voltage which is fed into the PADRE. No ice bath cold junction is used with this circuit. In the usual temperature measurement, the "hot" junction of the thermocouple is located on the model and the "cold" junction, usually in an ice bath, is located outside the tunnel. The output from this thermocouple is then fed into the PADRE.

17. In the measurement of aerodynamic forces and moments of models in the wind tunnel it frequently happens that the model is subjected to considerable vibration. For example, in the case of a model in the intermittent wind tunnel, the starting shock passes over the model and momentarily causes severe vibration of the model. The effect of this vibration is to cause the strain gages to have a large modulation of their 60 cps outputs. This modulation causes severe overloading of the servo-amplifiers with the result that they are more or less paralyzed, so that it is difficult or even impossible to get a satisfactory measurement under these conditions. To combat this trouble, the electro-mechanical filter shown in Figure 5 has been made. As shown in Figure 2, one channel of this filter is connected across each strain gage output. Thus the filter is connected outside the servo-loop and, therefore, does not upset the servo-stability. Each channel of the filter consists of a galvanometer coil mounted in a strong magnetic field. The resonant system formed by the moment of inertia of the coil and the stiffness of its wire suspension causes the filter to have a very high motional impedance at the resonant frequency and a very low impedance at all other frequencies. The wire suspension is carefully adjusted to give resonance at exactly 60 cps. The filter greatly reduces the modulation from vibration of the signal fed into the servo-system and thereby greatly reduces amplifier overloading. The use of the filter frequently makes it possible to obtain measurements which could not otherwise be secured.

18. Signal source impedance or resistance up to about 200 ohms is generally satisfactory for the PADRE. However, it is desirable to have the source impedance or resistance as low as possible.

19. The slewing speed of the servo-systems is 500 counts per second, which is approximately one-tenth that of the capability of the digital converters. Figure 4 is a photograph of one channel of the PADRE servo-system. The big dial on the front can be read to one count. The one-turn potentiometer shaft carrying the dial pointer is connected through gears so that the digital converter has the same reading as the dial. The signal attenuating network is located on the upper right-hand corner of the panel, and the centering potentiometer is located on the corresponding left-hand corner. Under the centering potentiometer are located the capacity and resistance balancing controls. Immediately beside the centering potentiometer is the range switch, which controls the magnitude of the reference alternating current running through the potentiometer. The amplifier is located in the extreme left end of the chassis. The main potentiometer and servo-motor are located in the chassis directly behind the dial.

20. Figure 6 shows an over-all view of the PADRE including the relay rack carrying all the units and 026 IBM Card Punch, which is setting beside the relay rack. The top panel of the relay rack contains either the serial numbering device or the clock-time device, whichever is used. Under this panel are seven servo-channels, and finally at the bottom are the power supply and the punch controller.

21. A rear view of the relay rack is shown in Figure 7. The power supply can be seen on the left, with the punch controller on the bottom right. Also on the panel at the bottom is the plug cable used for arranging IBM card layout.

22. A digital converter is an electro-mechanical device which translates the analog shaft position of the servo-system (when balanced) into electrical contact closures. These closures give a digital numerical value to the shaft position and can be arranged to give this information in the form of binary, decimal, or other system. The binary system and variations of it are frequently favored because of the simplifications which can be realized. However, the straight decimal system was chosen for the digital converter used in the PADRE so that anyone can immediately understand the quantitative information recorded without the necessity of decoding or going from a binary system to a decimal system through a conversion.

23. Essentially the digital converter developed for PADRE makes use of four stationary ten-segment commutators with

rotating brushes. The rotating shafts carrying the brushes are connected to one another through gearing of ten-to-one ratio as follows:

The units shaft registers			10	counts	for	one	shaft	revolution
"	10's	"	"	100	"	"	"	"	"
"	100's	"	"	1000	"	"		"	"
"	1000's	"	"	10,000	"	"	"	"	"

Thus there are three sets of gears, each with a ten-to-one ratio. The digital converter as used in the PADRE, however, never registers over 1999 counts but returns to 0000 when one more count is added. If the servo-system is set on a reading of 1000 for a zero input, then the variable under measurement either can go 1000 counts up (i.e., 1000 to 1999) or it can go 1000 counts down (1000 down to 000). A simplified circuit diagram and a photograph of one of the digital converters are shown in Figures 8 and 9, respectively.

24. Means are provided in the digital converters to prevent any brush from simultaneously contacting two segments of a commutator. For this purpose, a pawl and toothed wheel operate on the units shaft, which at readout place the units brush in the middle of the correct segment. If the tens brush is about to make contact on two segments of the tens commutator, a solenoid rotates the commutator (capable of only one-tenth of a revolution) so that the brush avoids the double contact and is placed squarely on the correct segment. For the hundreds and thousands commutators, a double arrangement with relays is used which always selects the correct brush. In this way, double contacts are completely avoided, and the brushes make contact with the correct segments only. The brushes on the units and tens shafts are disengagable and are always out of contact (disengaged) with the commutators except at readout, at which time a solenoid forces the brushes up against the commutators. This arrangement completely eliminates both brush friction and brush wear for these two shafts. On the hundreds and thousands commutators, however, the brushes are not disengagable and so are always in contact with the commutators, but the revolutions made by these shafts are so greatly reduced by the two ten-to-one gear sets between shafts that friction and wear are reduced to negligible proportions. All commutators are made of sterling silver, as are the brushes on the hundreds and thousands shafts. The disengagable brushes on the units and tens shafts are made of Ni-Span-C spring wire.

General Specifications of NOL Digital Converters

25. Some of the more important characteristics of the NOL digital converters are given below.

Over-all size, including lucite dust cover:

Height	6 3/8	inches
Width	7	inches
Depth	8	inches
Weight	7	pounds

Electric power required to operate solenoids and relays for readout: 2.5 amps, 24 V dc

Plug connections:

Cinch 15 terminal for output reading
Cinch 7 terminal for energizing relay and solenoid coils

Number of decimal digits: 4

Maximum slewing speed: 5000 counts/second

Torque to start rotating tens shaft: 0.200 in. oz. (100 counts/revolution)

Torque to start rotating units shaft: 0.020 in. oz. (10 counts/revolution)

All shafts locked during readout.

No additional relays are needed in the readout circuit.

The four decimal digit electric circuit closures are complete and independent.

Serial Numbering System

26. A serial numbering system has been provided in the PADRE so that each IBM card can be numbered serially every time the card is filled with punches. Usually in making a measurement it is desirable to apply zero input to the servo-systems immediately after the servo-system digital converters have been read out so that a "zero reading" can be punched in the card.

The value of the measurement then is equal to the data reading minus the zero reading. If the first reading is the data reading, it will fill up the first half of the IBM card, and the zero reading will fill up the last half. Since only one serial number is all that is required to identify this card, a geared cam arrangement has been provided on the punch controller (this device is described later) which operates a switch for every other punch controller cycle. The signal from this switch then operates the serial numbering device and the digital converter here is advanced one number for every other cycle of the punch controller. Also, the switch on the punch controller is arranged so that, if desired, the switch closes for each cycle of the punch controller and the serial number is advanced one count every time the punch button is pressed.

27. Inserted in the serial numbering system is a relay which can, if desired, prevent the serial number from being punched in the card whenever the serial number is not advanced. By this means, needless duplicative punches in the card are avoided so that the columns saved can be used for other purposes.

28. Frequently fewer than 999 cards are required for recording the data of a test. When this is the case, only three digits need be punched. Hence the first digit of the four available in the serial numbering digital commuter can be eliminated, thus saving one more column in the IBM card. This can easily be accomplished by suitably modifying the "plug cable" described later.

Digital Converter for Indicating Clock Time

29. One of the digital converters has been modified for recording minutes and hours, or clock time, in terms of decimal numbers by means of a 60 cps synchronous motor. In this case one tenth of a minute (6 seconds) registers as one count, i.e., one revolution of the units shaft equal one minute, since there are ten segments on the units commutator. The tens commutator has ten segments also, and hence, it registers 10 minutes for one revolution. The hundreds shaft, however, has been replaced by a six segment commutator so that it registers 60 minutes, or one hour, for a revolution. The thousands shaft then registers 10 hours for one revolution. Thus, this digital converter runs for 10 hours before repeating and gives one count for each six seconds. It can be used in the "serial numbering" set-up to provide minutes and hours after the start of the test.

Tests and Reliability of Digital Converters

30. Digital converters, which are quite complex devices for converting shaft rotation to digital contact closures of electric circuits, must function perfectly and must be very reliable. Suitable commercial versions were not available when the development of the PADRE was begun, so that development of a digital converter for NOL use was initiated. In order to achieve the near perfection and reliability required of the digital converter, it was necessary to subject the design to millions of life test operations to find the weak features and eliminate them one by one, until a satisfactory over-all design was evolved.

31. The NOL digital converters have been developed with the aid of a testing procedure designed to show up faults. First of all, the final designs of all individual parts subject to malfunction have been determined by testing parts to failure and modifying the designs for improvement, until all designs were found capable of operating at least 1,000,000 times without failure. The parts particularly tested and modified included such items as links and pins, springs, flexing wires, bearings, and brushes.

32. Over-all tests of the digital converters were made during their development and are repeated every time a digital converter is serviced. For this purpose, a life tester and fault finder, shown in Figure 10, has been built which compares two digital converters, A and B, against each other. The digital converters are connected together mechanically so that they always read the same number. A small motor is connected to the two digital converters and gives a random (more or less) number of revolutions to the units shafts. The motor is then stopped. Energizing current for readout is then applied to both the digital converters. First, the tester checks digital converter A for blank columns (misses) and double punches, then checks digital converter B for the same faults. Finally, the tester compares the electrical contact closures indicating the reading of A against those of B. If the contact closures are not identical, a wrong number is indicated. If no faults (misses, double punches, or wrong numbers) are found, the tester then automatically causes the motor to advance the digital converter to some new reading and repeats the process. The testing continues until either a fault is found or until the tester is manually shut down. However, when a fault occurs, the tester stops instantly and indicates the type and location of the fault. The digital converters are then examined by the test operator

who can usually find the exact cause of the fault and take steps either to make repairs or to modify the design.

33. It has been found from a study making use of probability theory that a digital converter has a probability of about 0.999 of being completely free of faults if it will operate 50,000 times without a fault. Actually the test is seldom carried so far. Fifteen or twenty thousand fault-free readouts give a very good probability of freedom from faults. This number of tests made at the rate of 26 readouts per minute (fault tester rate) takes between one and two days of eight-hour operation. It is essential that each digital converter be as fault-free as possible, since up to eight converters are used in the PADRE, and the probability of trouble is therefore multiplied by eight. Ever since this fault tester has been used for testing the digital converters, very little trouble has been experienced with the PADRE.

Punching the IBM Card

34. As can be clearly seen in Figure 5, the IBM Card Punching Machine is equipped with a keyboard which makes it possible for an operator to punch IBM cards manually. This machine not only punches the data into the cards, but it also prints numbers at the top edge of the card. The machine also is equipped with a cylinder on which an IBM card containing control commands can be mounted, the function of which is automatically to control the IBM cards being punched; e.g., any columns desired can be duplicated from the last card punched. Also, columns can be skipped in any sequence desired by punching the proper commands into the control card.

35. When used with the PADRE, the IBM 026 Card Punching Machine is modified by the addition of a Cinch plug which permits the running of a cable to the PADRE so that digital converter circuit closures can cause the punching machine to punch the correct holes in the IBM cards when reading out the information held in the digital converters. To do this, it is necessary to provide a device called a "punch controller" between the digital converters and the 026 Card Punch. This is shown in Figure 1, and a simplified circuit diagram is shown in Figure 11. Since the 026 Card Punch Machine punches the columns consecutively, the punch controller must read out one digit at a time in sequence and transmit the digit to the card punch machine and also give a current pulse at the right time and of the right duration to punch each digit. One terminal on the 026 Card Punch Machine might be called the

"punch command" terminal. If it is connected to any one of the terminals for the digits between 0 and 9, or to the space, or to the X or Y punches, it will cause this number, character, or space to be punched in the column under the puncher. However, unless the circuit closure generating the punch command current pulse is closed for a fairly precise period of time, the card punch machine will not perform satisfactorily. The correct duration of this closure is of the order of 15 milliseconds, a requirement which must be met by the punch controller.

36. A photograph of the punch controller is shown in Figure 12. Basically the punch controller consists of a stationary commutator of 50 segments and a rotating brush. Never more than 40 of the 50 segments on the punch controller are used, the unused segments providing a dead space in which the brush arm can be accelerated from its normal resting position up to the proper speed (constant) before encountering "live" segments and, after contacting the last of the 40 live segments, providing a space for decelerating to the normal resting position again. Thus, the arm makes one revolution for one readout of all digital converters. The brush on the arm successively makes contact with each of the live segments, each of which is connected by a wire to a particular brush on a particular digital converter. At readout all brushes in the digital converter are locked in their proper places. Each particular brush then is setting on a segment corresponding to some number between 0 and 9, inclusive, so that the circuit is now complete as to the proper terminal on the card punch machine to punch the number corresponding to the brush position. Then a pulse of command current is applied to this circuit set-up and causes the machine to punch the hole for the segment on which the digital converter brush is sitting. When the punch controller brush now moves to the next segment, the next digital converter commutator is read out, and so on through all digital converters. Spaces, and X and Y punches, can be interspersed as desired between digital converter readouts by proper connections in the plug cable described below.

37. Since the command pulse of current must be of carefully controlled duration, as stated previously, it is necessary to provide a means of creating pulses of this duration while the brush is in the middle of each of the 50 segments of the punch controller commutator. For this purpose an additional small commutator, having one segment occupying about one third of the circumference, rotates at fifty times the speed of the arm carrying the brush over the 50-segment commutator.

Two brushes ride on the single-segment commutator to provide continuity between the brushes when both brushes are contacting the single segment at the proper times. As a result, a command current pulse of 15 milliseconds duration is generated. To eliminate sparking between this commutator segment and the two brushes, a capacitor, resistor, and rectifying element are connected between the brushes. This is a necessary requirement since the sparking would reduce the life of the brushes and segment to an unacceptably small number of operations before failure. With this arrangement, the main 50-segment commutator and brush do not break any current; it has been found that they remain in perfect working condition even after years of use.

38. The punch controller is driven by a small (1/200 hp) synchronous motor controlled by cam-operated microswitches. When the brush passes the 40th (last live) segment, the motor current is automatically cut off and the motor stops with the brush in the middle of the ten unused commutator segments. A manually operated push button is used to initiate the readout by closing the circuit for starting the motor. After all live segments are scanned by the brush, the above microswitch shuts off the motor, stopping the brush in the middle of the 10-segment stretch.

39. The pattern of the IBM card to be punched is controlled by means of a plug cable. This cable is about one foot long and has a 50-terminal plug on each end. By arranging connections between the terminals of the plugs on each end, it is possible to punch the readouts from the digital converters in any order desired, to skip any digits not needed, and to insert spaces between each four digits of the digital converters. The purpose of inserting spaces between each four digits is to make it easier to read the printed numbers appearing at the top edge of the IBM card. The plug cable is exactly equivalent to the usual IBM plug board.

40. When the PADRE is not actually in process of being readout, any supplemental data desired can be manually punched into the IBM card by the regular punch keyboard. To provide absolute independence between the card punch keyboard and the digital converters, a relay has been provided in the PADRE so that the PADRE is actually connected to the card punch machine only during readout. If it is desired to duplicate supplemental data in each IBM card, this can be done by suitably punching the proper commands into the control card carried on the cylinder of the IBM 026 Card Punching Machine.

41. When all seven channels and the serial numbering set-up

are being used, the IBM card is exactly half filled by each readout. Each of the seven channels with four digits and one space fills up thirty-five columns of the card. The serial numbering setup, or clock time setup, can fill up four more digits and one space, making up the total of forty. However, there is no need to record the serial number twice on each card, so that it may just as well be omitted every other readout. Thus, on the over-all card only 75 of the 80 columns are used, which leaves five columns free for supplemental data.

42. At the instant a readout is to be made (by pushing the readout button), all shafts of all digital converters are locked in at the reading positions. In effect, this does not prevent taking readings periodically "on the fly" with equal time intervals between them. During readout, the servo-motors are reconnected and the digital converter shafts are unlocked. Then the servo-systems are free to "catch up" to the input signals which may have changed during the readout, and the servo-systems can balance now at the new values. Then the next readout can be made, and so on. In effect, this amounts to taking readings on the fly.

43. The frequency with which readouts can be made is limited by the speed of the card punching machine as well as by the servo-systems. The 026 IBM Card Punching Machine can punch a maximum of 20 columns or punches per second. For use with the PADRE, only fifteen punches per second are used. Hence, if forty columns are to be punched, the time required for the punching is 40/15 = 2 2/3 seconds. The punch controller, however, makes one cycle in three seconds, so that three seconds is actually required for the readout itself. Then, in addition, the servo-systems require time for catching up for the next reading. At most, this requres an additional five seconds, making a total of eight seconds between readouts. If, however, the signals do not change very much in magnitude between readings, the time required for catching up is much less, perhaps two seconds. Under these circumstances it is possible to make a readout every five seconds, which is about the fastest possible for the PADRE in routine use.

General Precautions

44. There are a few common-sense precautions which should be observed in order to get best results in using the PADRE.

a. The PADRE chassis should always be grounded. The

thermocouple circuits should be grounded in one place and only in one place. They may be grounded either in the servo-systems or in the model. Either of these places for grounding is generally satisfactory. Floating circuits and doubly grounded circuits cause unsatisfactory operation.

b. The servo-phase angle balance for a given gain setting must be carefully made to give the maximum servo-stiffness. The gain control must be set to give the greatest servo-stiffness without oscillation.

c. The IBM cards should be inspected occasionally during data taking to see that data look reasonable. One should especially look for things which are obviously wrong.

CONCLUDING REMARKS

45. The main features of PADRE are summarized here. This instrumentation provides a means of automatically punching IBM cards to record data on pressures, forces and moments, temperatures, small temperature differences, mean square values of turbulence, positions of probes during boundary-layer surveys, angles of attack of models in wind tunnels, and any other quantity represented by a voltage, either A.C. or D.C. Seven channels with servo-systems and digital converters of four decimal digits each are provided, as well as means of automatically punching a serial number into each card or punching the clock time. Because of its protability and versatility, PADRE is particularly useful for research work requiring special set-ups.

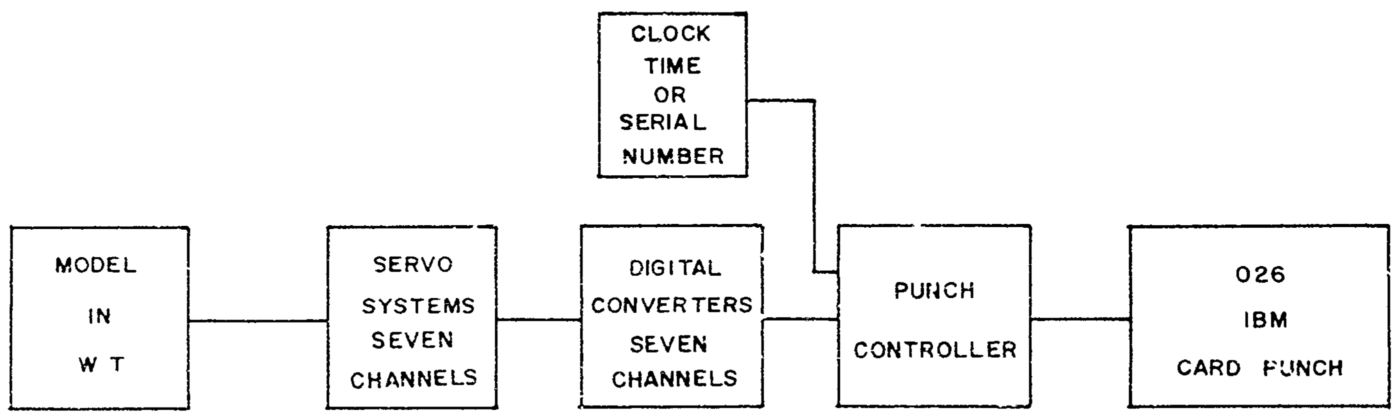

FIG. I ELEMENTS OF PADRE

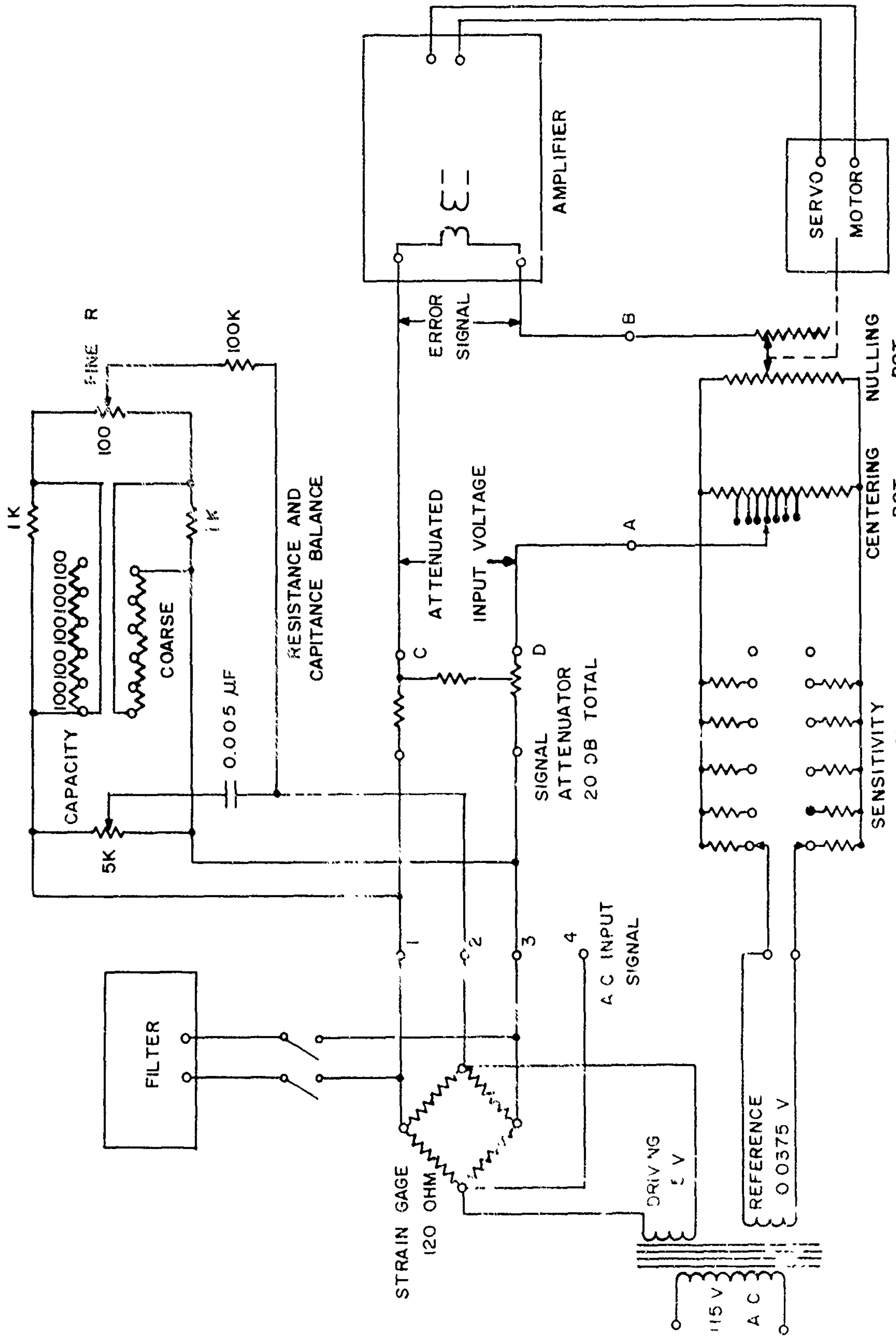

FIG. 2 A.C SERVO SYSTEM UNIT SCHEMATIC CIRCUIT DIAGRAM

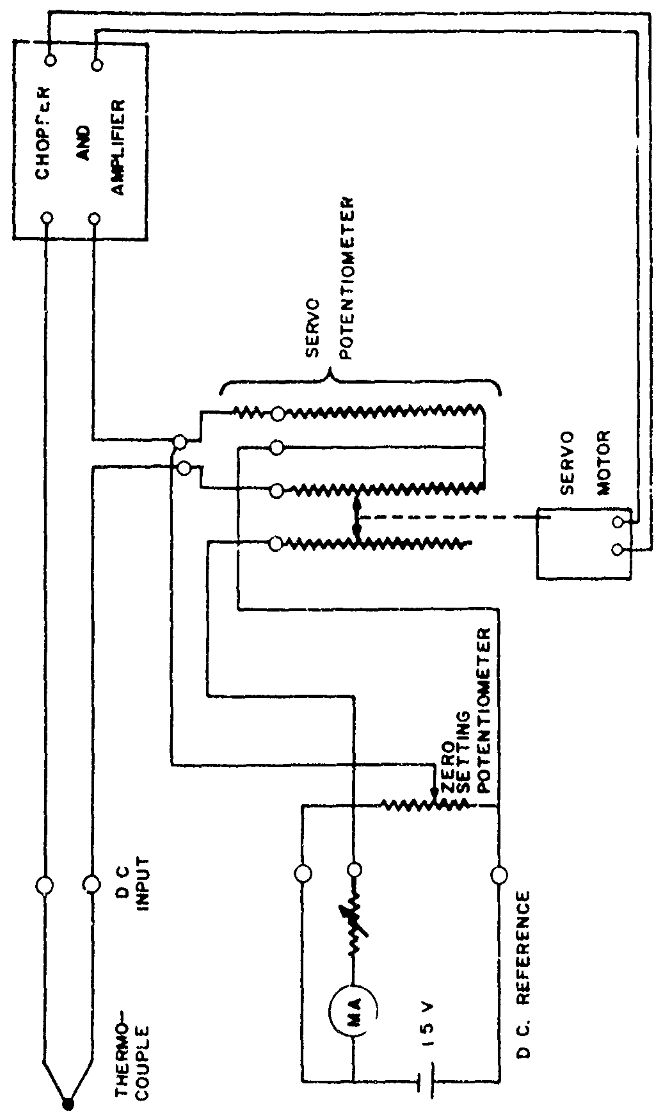

FIG. 3 D C. SERVO SYSTEM UNIT SCHEMATIC CIRCUIT DIAGRAM

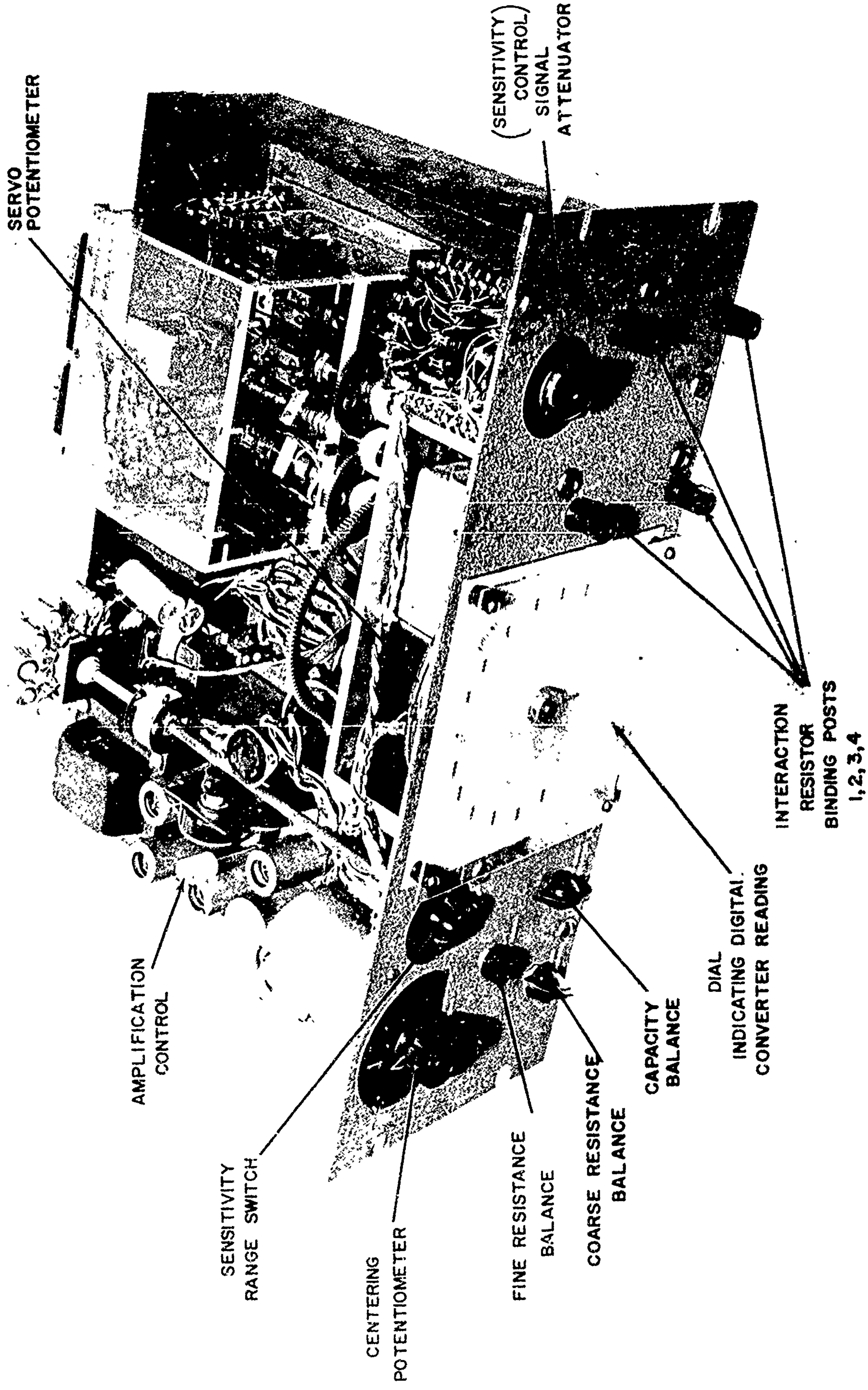
SERVO POTENTIOMETER
(SENSITIVITY CONTROL) SIGNAL ATTENUATOR
AMPLIFICATION CONTROL
SENSITIVITY RANGE SWITCH
CENTERING POTENTIOMETER
FINE RESISTANCE BALANCE
COARSE RESISTANCE BALANCE
CAPACITY BALANCE
DIAL INDICATING DIGITAL CONVERTER READING
INTERACTION RESISTOR BINDING POSTS 1,2,3,4

FIG. 4

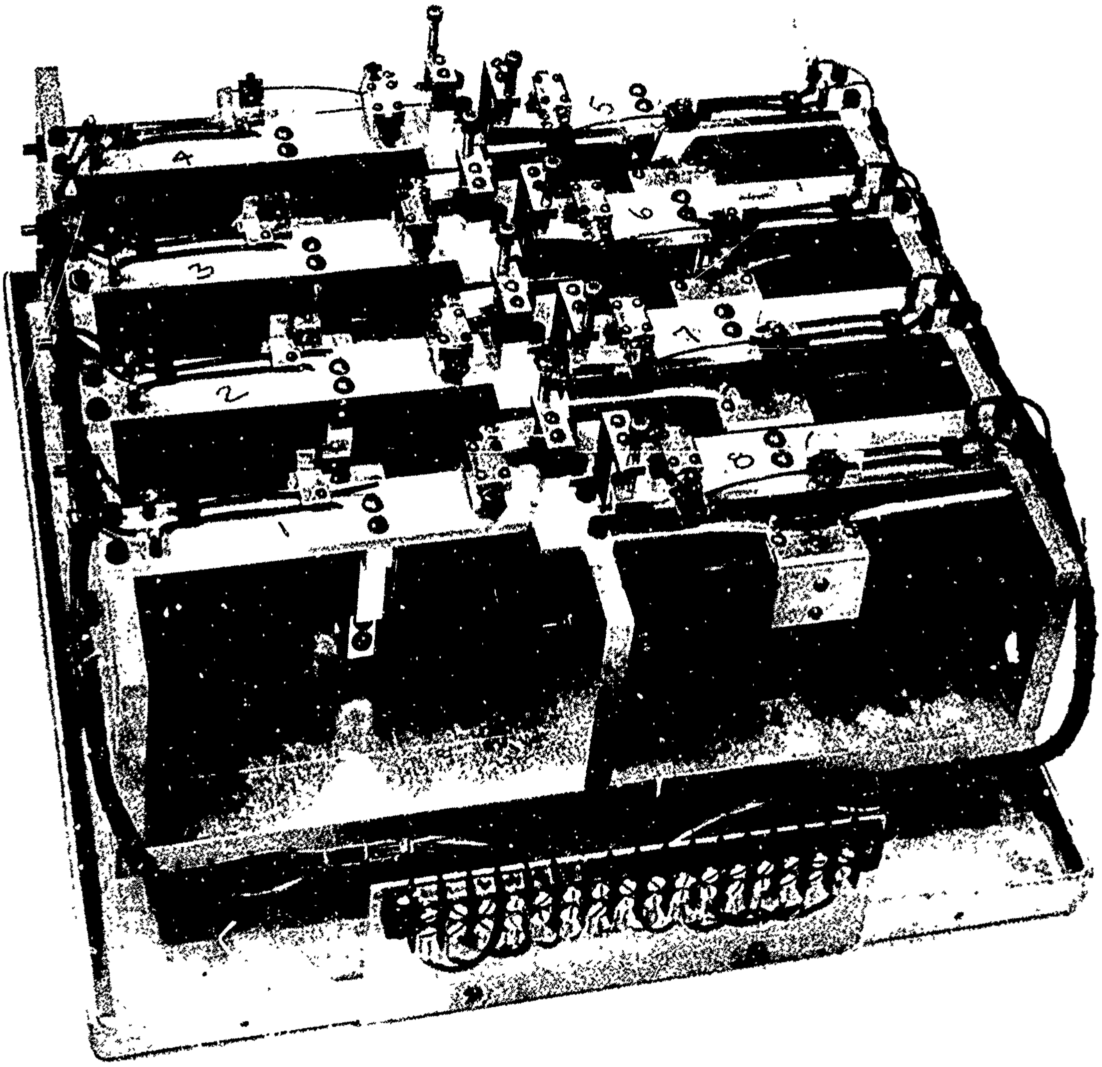

FIG. 5 ELECTRO-MECHANICAL FILTER FOR REDUCING EFFECT OF MODEL VIBRATION

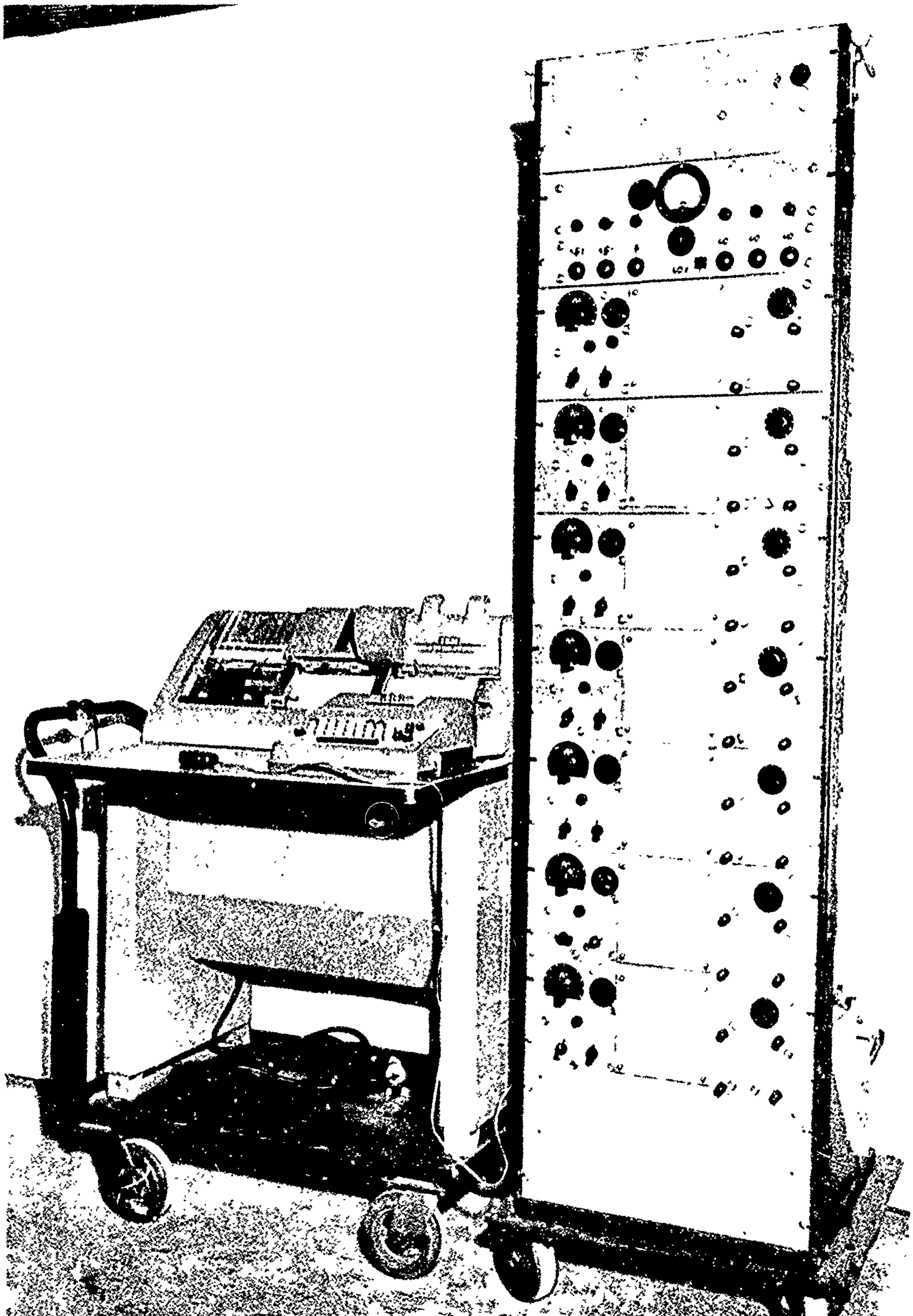

FIG. 6 OVER-ALL VIEW OF PADRE

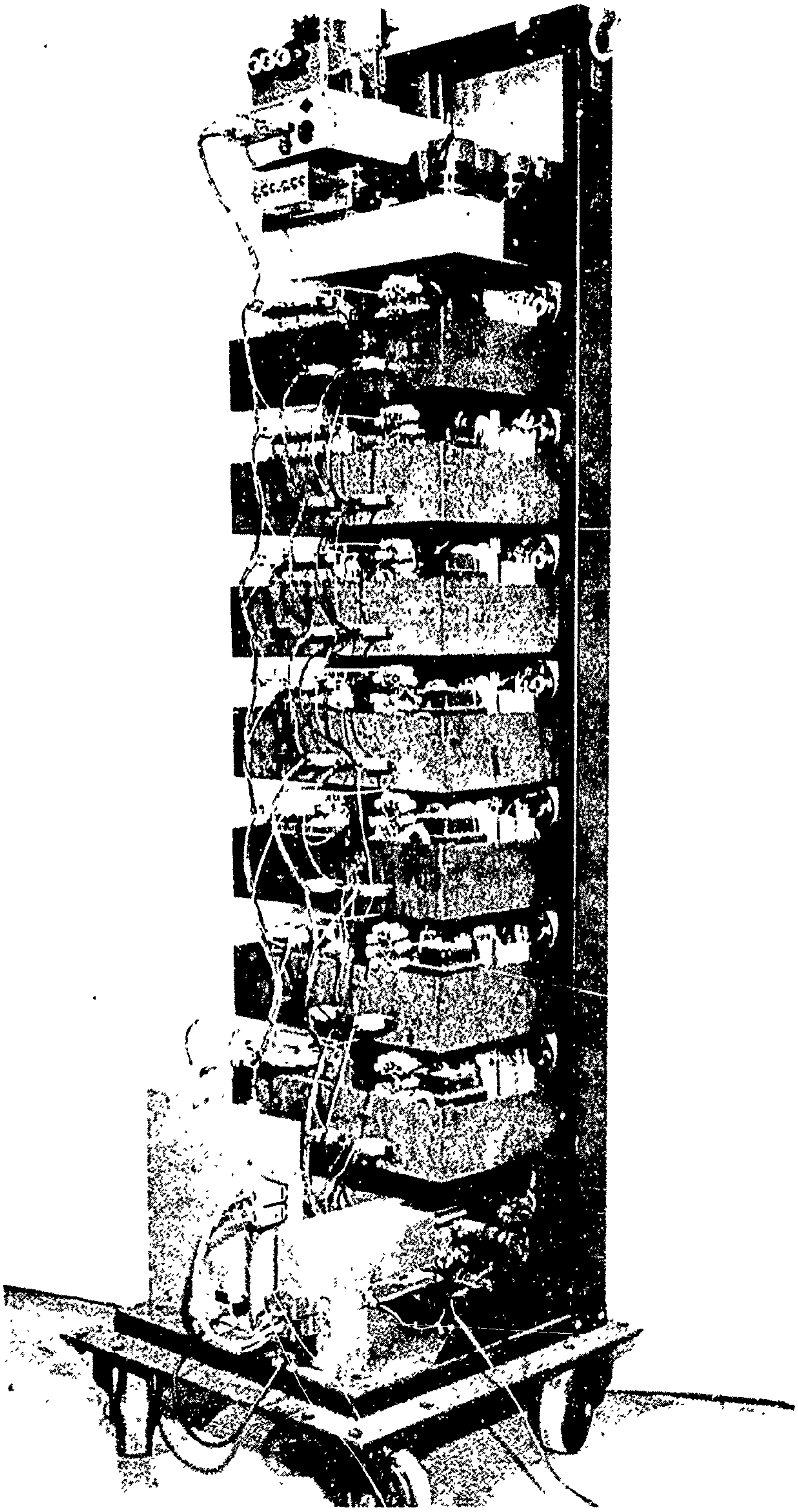

FIG. 7 REAR VIEW OF PADRE

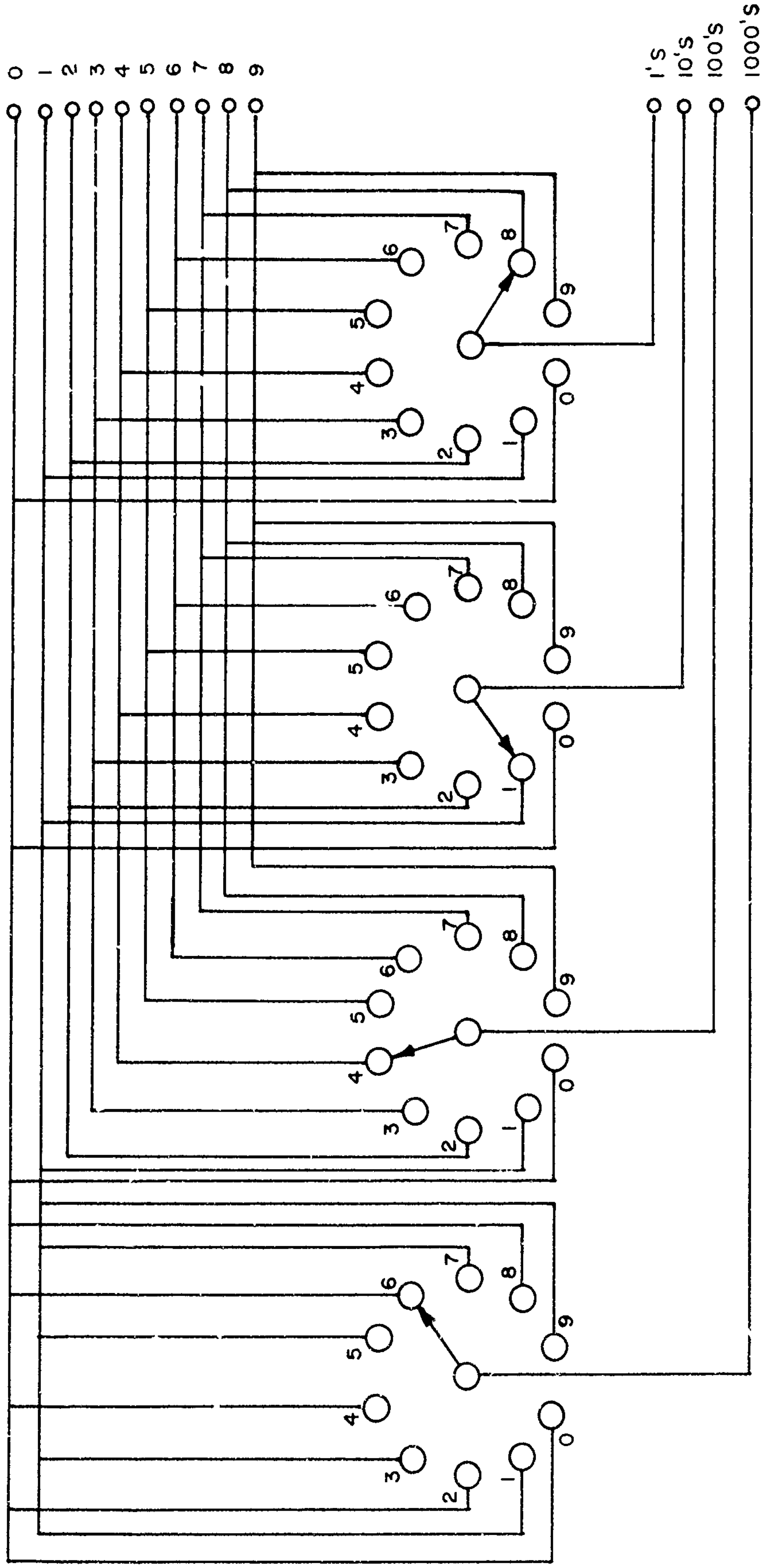

FIG. 8 SIMPLIFIED CIRCUIT DIAGRAM OF DIGITAL CONVERTER

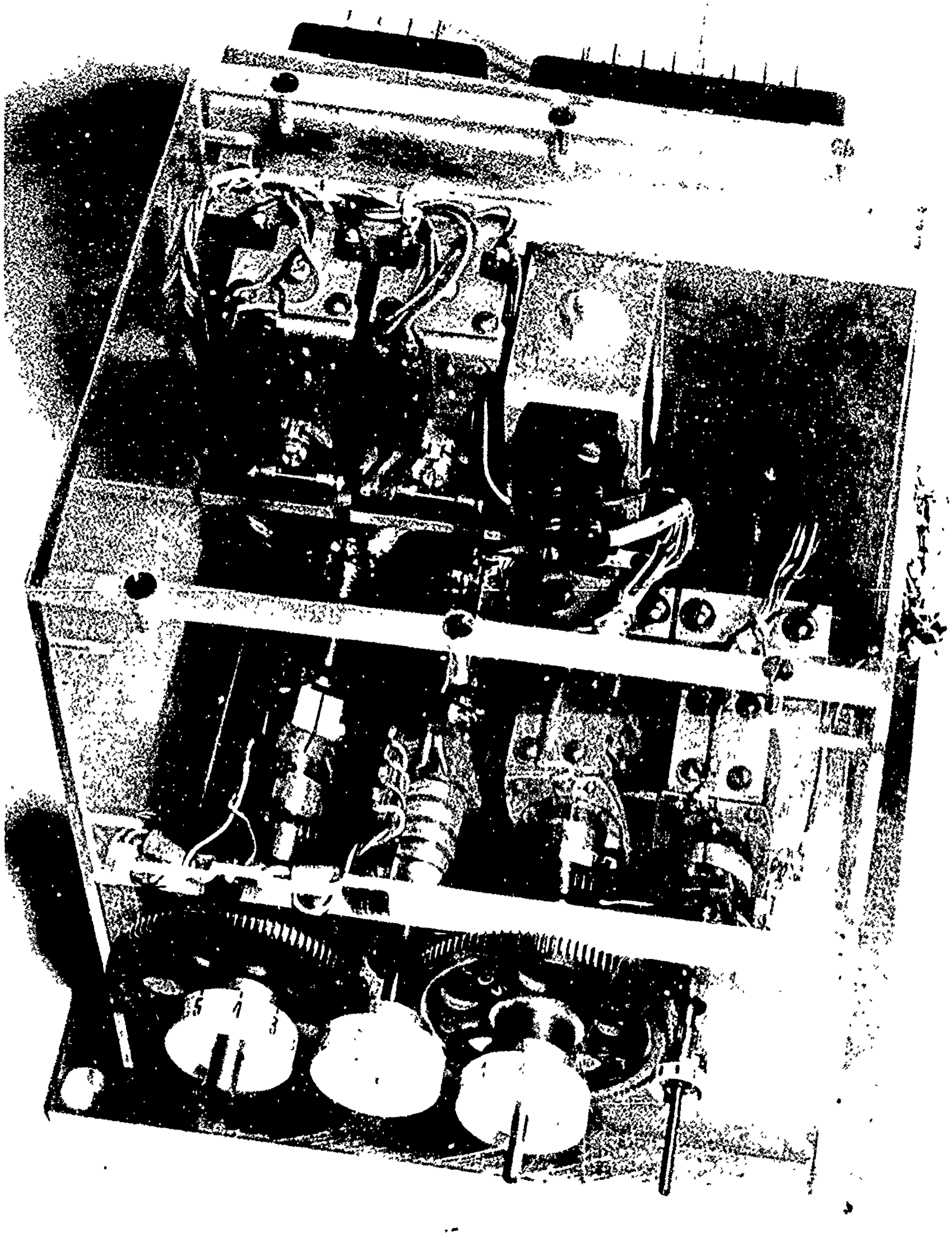

FIG. 9 DIGITAL CONVERTER USED IN PADRE

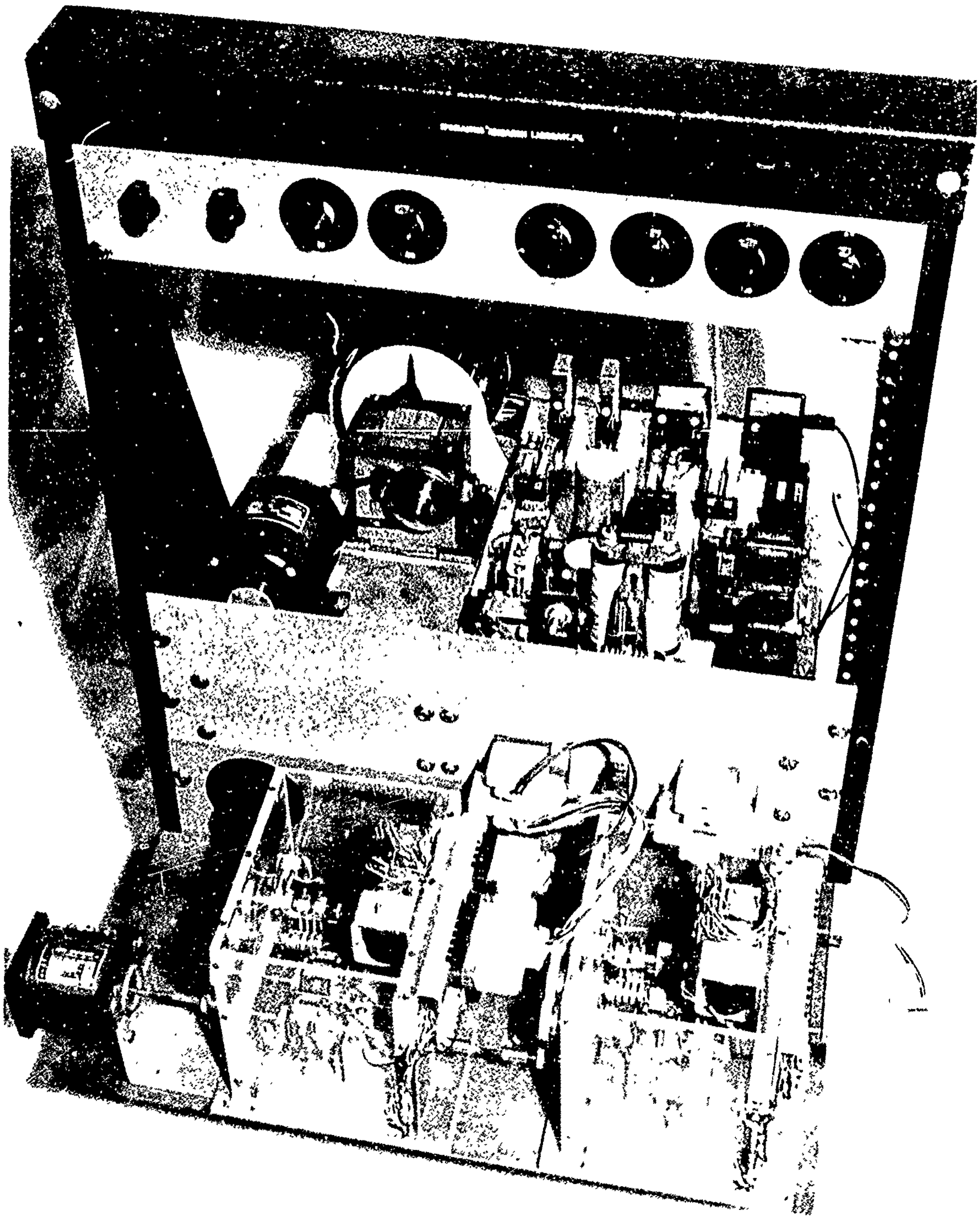

FIG. 10 TESTER FOR DIGITAL CONVERTERS

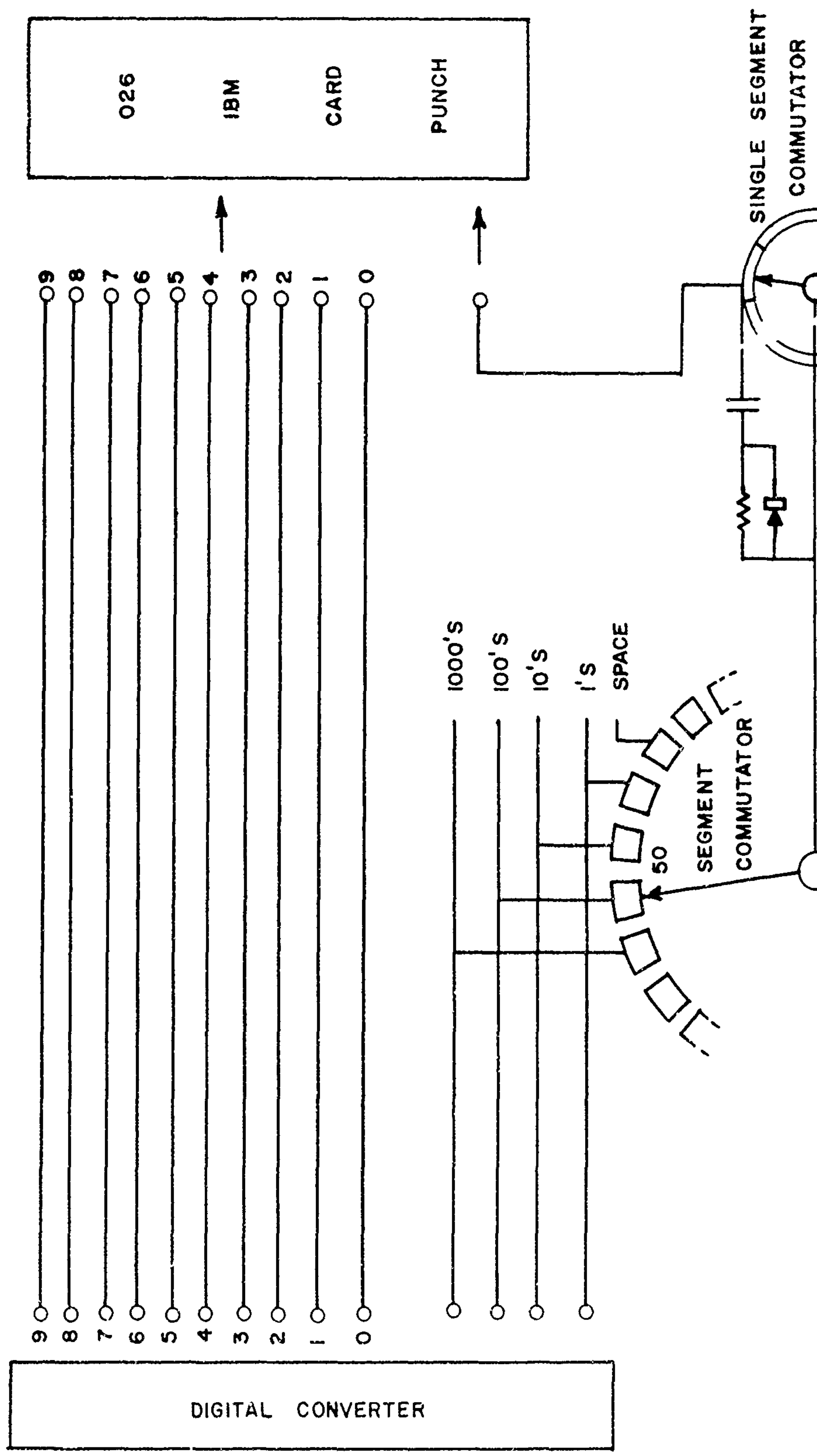

FIG. 11 PUNCH CONTROLLER SCHEMATIC CIRCUIT DIAGRAM

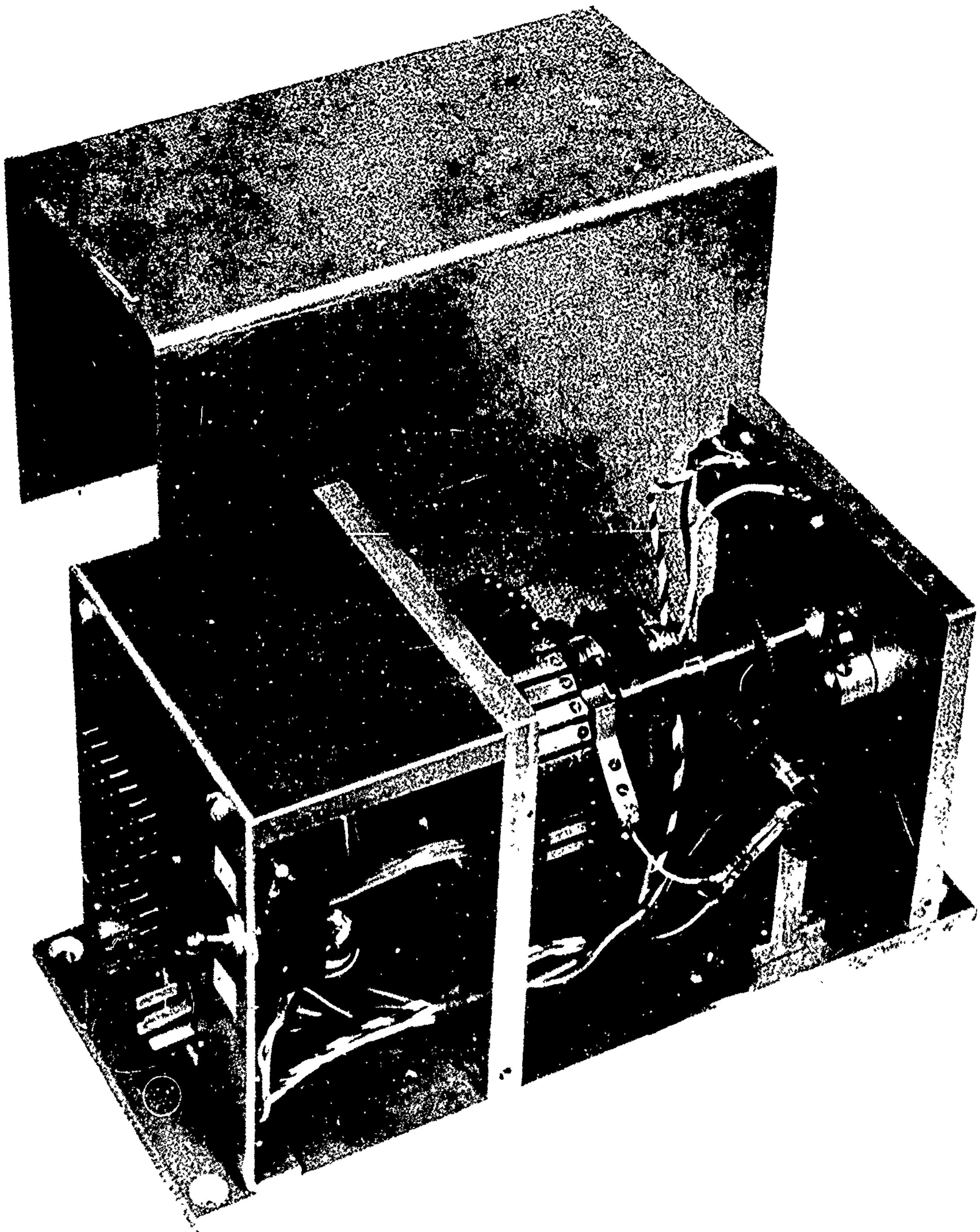

FIG. 12 PUNCH CONTROLLER TO
READOUT DIGITAL CONVERTERS

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